

# SCINTILLATION MATERIALS



## Kuraray's Scintillation Materials Plastic Scintillating Fibers SCSN Plastic Scintillators

The history of Kuraray's scintillation materials dates back to 1982, when we put new plastic scintillators on the market. These unique plastic scintillators were named SCSN and gained public favor all over the world.

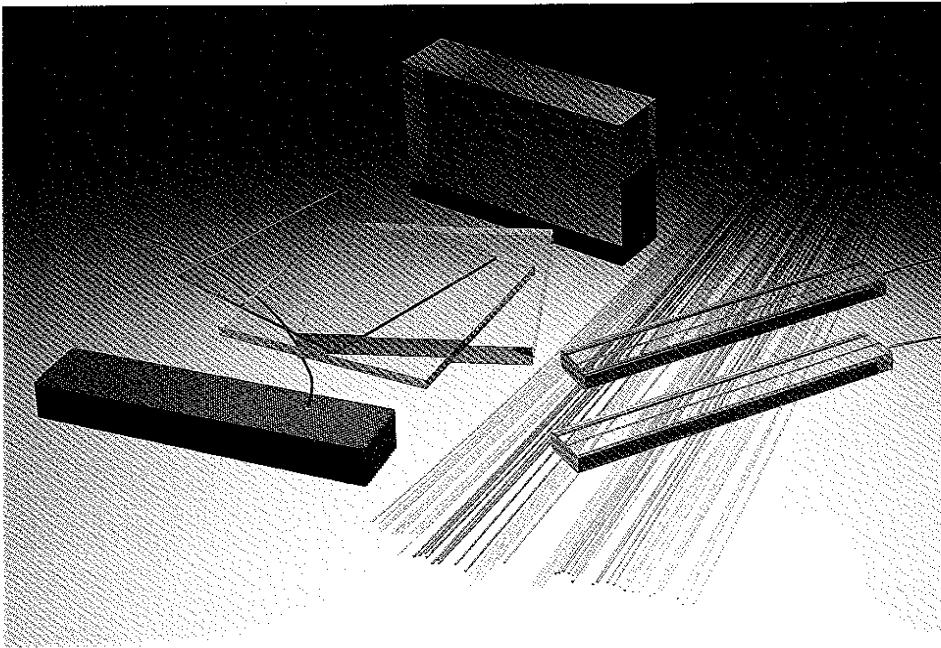
After plastic scintillators, we developed scintillating fibers, wavelength sifting fibers and clear optical fibers in 1990. Having excellent stability of properties, Kuraray's plastic fibers are trusted by many scientists and technical experts.

As pioneer in the world, we developed multi cladding fibers which have 50% higher light yield than previous single cladding fibers in 1993. It is well-known that Multi cladding fibers contributed to improvement of properties of fiber-detectors in the field of high energy physics.

Kuraray's scintillation materials play an active part not only in the scene of high energy physics, but in the scene of atomic energy. We hope to attract attention in the fields of medicine. There is strong potential for new applications in the future.

Since we have skill in splicing WLS fibers to clear fibers and assembling fibers into bundles and blocks, we can supply fibers in suitable shapes for your detectors.

This brochure presents only basic technical data. If you have further questions, please let us know at any time. We are looking forward to supporting your works and applications.



All data presented herein is based on actual measurements performed by Kuraray Co.,Ltd. Kuraray Co.,Ltd. accepts no liability for damage or loss resulting from the use or misuse of this information.

# Plastic Fibers

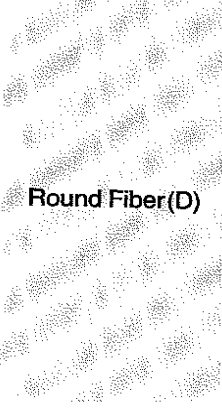
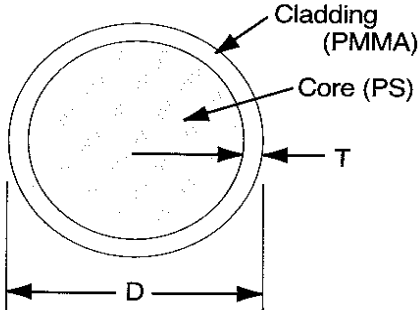
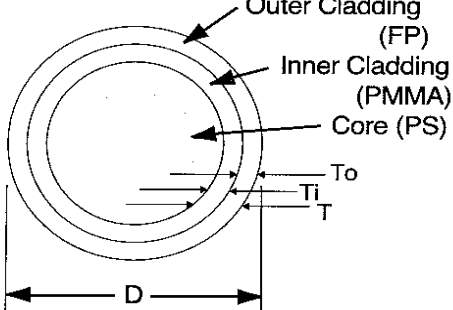

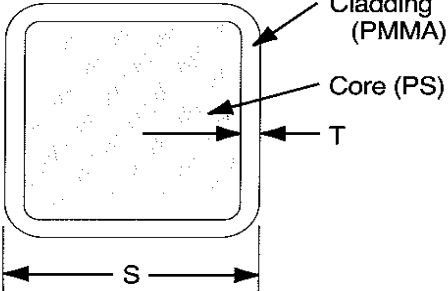
Scintillating Fibers  
Wavelength Shifting Fibers  
Clear Fiber

## Materials and Structures

### Materials

	Material	Refractive index	Density [g/cm <sup>3</sup> ]	No. of atom per cm <sup>3</sup>
Core	Polystyrene (PS)	$n_D=1.59$	1.05	C : $4.9 \times 10^{22}$ H : $4.9 \times 10^{22}$
Cladding	for single cladding inner for multi cladding	Polymethylmethacrylate (PMMA)	$n_D=1.49$	C : $3.6 \times 10^{22}$ H : $5.7 \times 10^{22}$ O : $1.4 \times 10^{22}$
	outer for multi cladding	Fluorinated polymer (FP)	$n_D=1.42$	

### Cross-section and Cladding Thickness

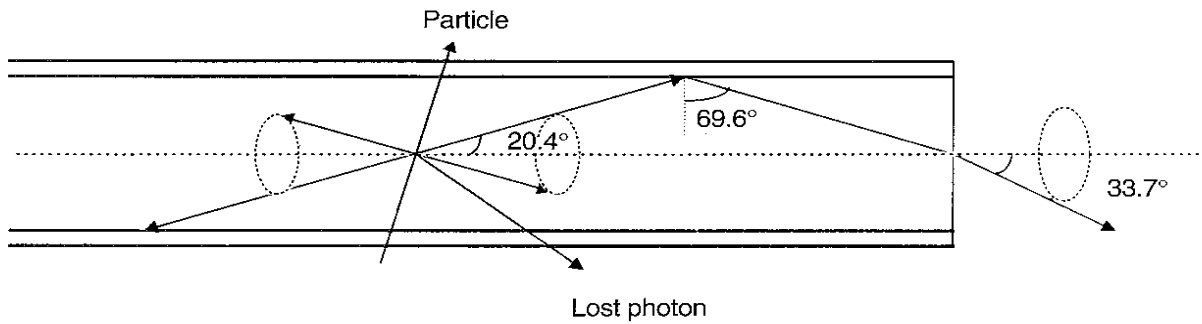
	Single Cladding	Multi Cladding (M)
 <p>Round Fiber(D)</p>	 <p>Cladding Thickness : <math>T=3\%</math> of D Numerical Aperture : <math>NA=0.55</math> Trapping Efficiency : 3.1%</p>	 <p>Cladding Thickness : <math>T=3\%</math> (<math>T_o</math>)+3% (<math>T_i</math>) =6% of D Numerical Aperture : <math>NA=0.72</math> Trapping Efficiency : 5.4%</p>
 <p>Square Fiber(SQ)</p>	 <p>Cladding Thickness : <math>T=2\%</math> of S Numerical Aperture : <math>NA=0.55</math> Trapping Efficiency : 4.2%</p>	<p>Not available</p>

## Cladding and Transmission Mechanism

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### Single Cladding

Single cladding is standard type of cladding.

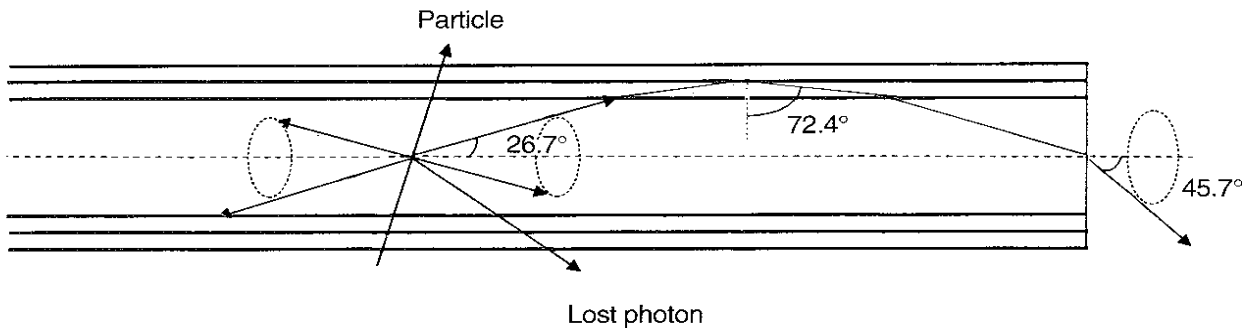


### Multi Cladding

Multi cladding fiber (M) has 50% higher light yield than single cladding fiber because of large trapping efficiency.

Clear-PS fiber of this cladding has extremely higher NA than conventional PMMA or PS fiber, and very useful as light guide fiber.

Multi cladding fiber has long attenuation length equal to single cladding fiber.



## Type of Polymer Orientation of PS Core

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### Standard type (Non-S type)

PS core is of almost no oriented polystyrene chain and is optically isotropic and very transparent. This conventional standard type has good attenuation length, but it showed weakness against clacking caused by bending or handling during assembling.

### S type (S)

Core has molecular orientation along drawing direction. This fiber is mechanically stronger against clacking at the cost of transparency. The attenuation length of this type is nearly 10% shorter than standard type. (See figures on page 9)

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## Dimensions and Tolerance

### Cross-sectional Dimension

Minimum : 0.2mm, Maximum : 2.0mm, typically as follows.

Round (Single and Multi Cladding) : 0.2, 0.5, 1.0, 1.5, 2.0mm dia.

Square (Single Cladding) : 0.2×0.2, 0.5×0.5, 1.0×1.0, 2.0×2.0mm side

<b>Tolerance of Diameter</b>	Cut Fiber(1~5m long) :	$\left  \frac{\Delta D}{D} \right  < 2.0\%$	for round fiber
		$\left  \frac{\Delta S}{S} \right  < 3.0\%$	for square fiber
	Endless Spool Fiber :	$\frac{3\sigma}{D} < 2.5\%$	( $\sigma$ : rms, Spool Dia. : 300mm or 900mm.)

## Bending Loss and Minimum Bending Diameter

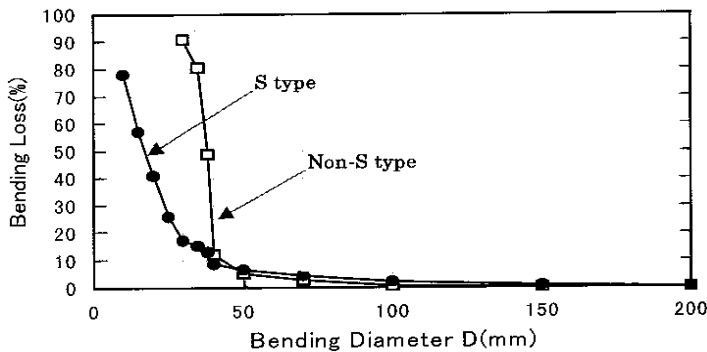
### Bending Loss

The following figure shows bending loss of Clear-PSM and Clear-PSMS.

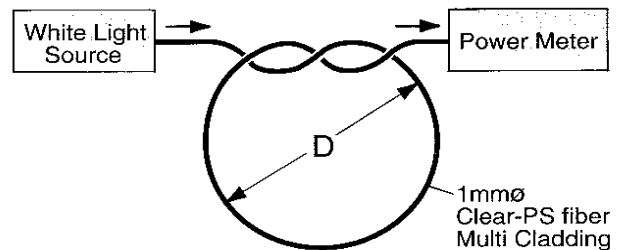
S type is better than Non-S type.

The rapid increase of bending loss of non-S type is due to cracking of core.

S type doesn't show such cracking.



### Measurement Method



### Minimum Bending Diameter

We recommend minimum bending diameter as the following table on safety side and long term reliability.

Type	2mm $\varnothing$ Fiber	1mm $\varnothing$ Fiber	0.5mm $\varnothing$ Fiber
S type	200mm	100mm	50mm
Non-S type	400mm	200mm	100mm

# Formulations

## Scintillating Fibers<sup>1)</sup>

Description	Color	Emission Peak [nm]	Spectra	Decay Time [ns]	Att. Leng. <sup>2)</sup> [m]	Characteristics
SCSF-38, SCSF-38M	blue	428		2.3	>3.0	General Use
SCSF-81, SCSF-81M	blue	437	See the following figure	2.4	>3.5	Long Attenuation Length
SCSF-78, SCSF-78M	blue	450		2.8	>4.0	Long Att. Length and High Light Yield
SCSF-3HF(1500), SCSF-3HF(1500)M <sup>3)</sup>	green	530		7	>4.5	3HF formulation for Radiation Hardness

1) Test fibers are Non-S type, 1mmø.

2) Measured by using bialkali PMT and UV light (254nm). Quality control is made by another measurement of the transmission loss every batch.

3) For example, "3HF(1500)M" means the concentration of 3HF dye is 1500ppm, the cladding is Multi cladding.

## Wavelength Shifting Fibers (WLS Fibers)<sup>4)</sup>

Description	Color	Emission Peak [nm]	Spectra	Att. Leng. <sup>5)</sup> [m]	Characteristics
Y-7 (100), Y-7 (100)M	green	490		>3.0	Green Shifter
Y-8 (100), Y-8 (100)M	green	511	See the following figure	>2.8	Green Shifter
Y-11(200), Y-11(200)M	green	476		>3.5	Green Shifter (K-27 formulation)
O-2 (100), O-2(100)M	orange	538		>1.5	Green to Orange Shifter

4) Test fibers are Non-S type, 1mmø.

5) Measured by using bialkali PMT and blue LED (445nm).

Otherwise than descriptions mentioned above, various WLS fibers are available.

Ex. R-3 (green to red shifter, peak is 607nm), Y-9 (blue to green shifter, 485nm), B-1 (428nm), B-2 (437nm).

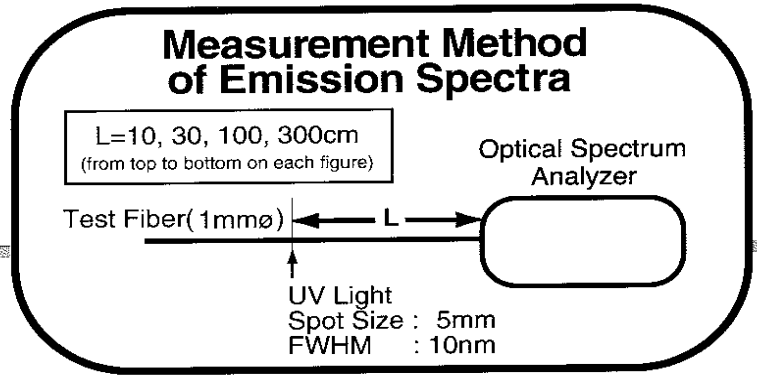
## Clear Fiber (Non-doped, Optical Fiber)<sup>6)</sup>

Description	Color	Emission Peak [nm]	Spectra	Att. Leng. [m]	Characteristic
Clear-PS, Clear-PSM	-	-	-	>10	depend on wavelength

6) Test fibers are Non-S type, 1mmø.

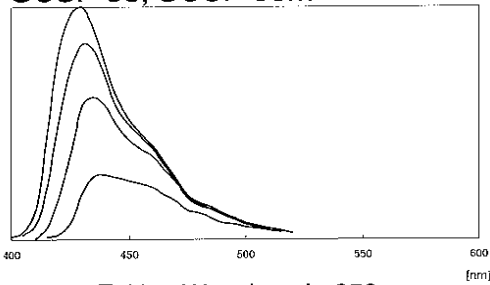
Transmission Loss data is shown on page 8 and 9.

# Emission Spectra

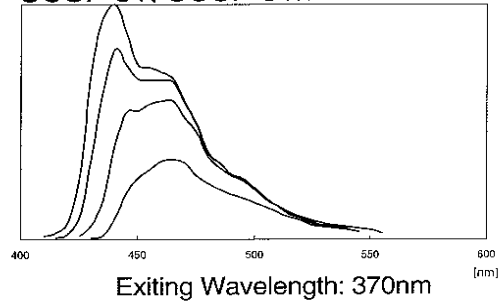


## Scintillating Fibers

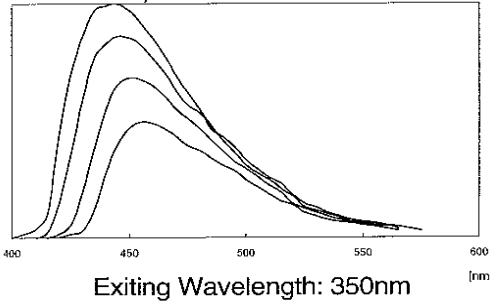
SCSF-38, SCSF-38M



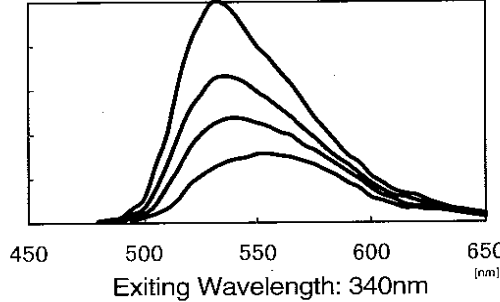
SCSF-81, SCSF-81M



SCSF-78, SCSF-78M

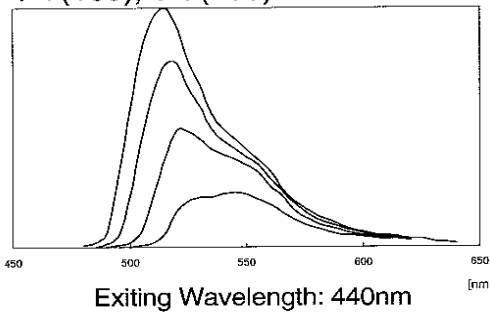


SCSF-3HF(1500), SCSF-3HF(1500)M

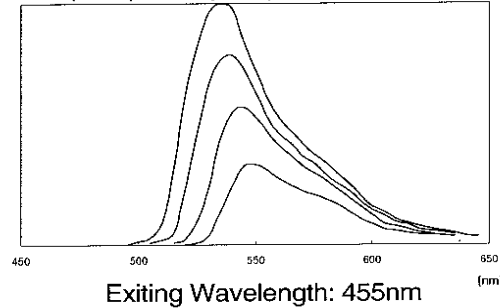


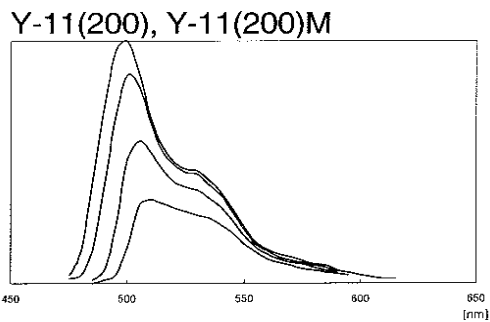
## WLS Fibers

Y-7(100), Y-7(100)M

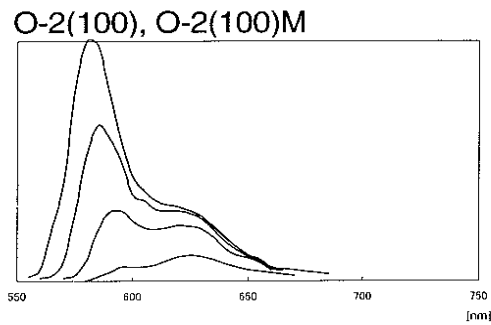


Y-8(150), Y-8(150)M



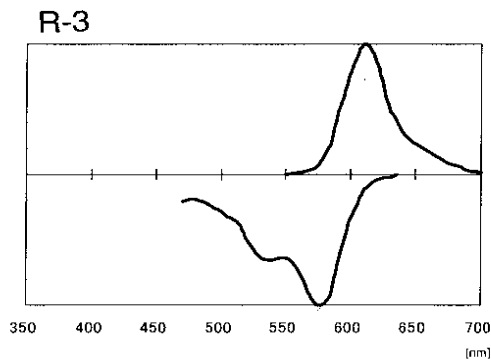
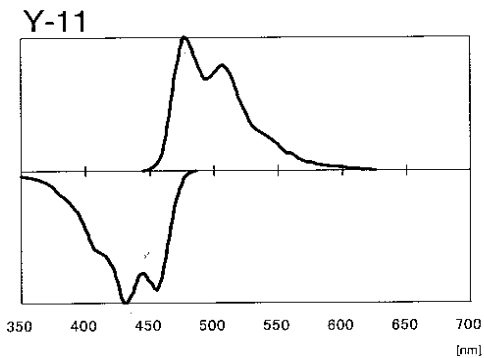
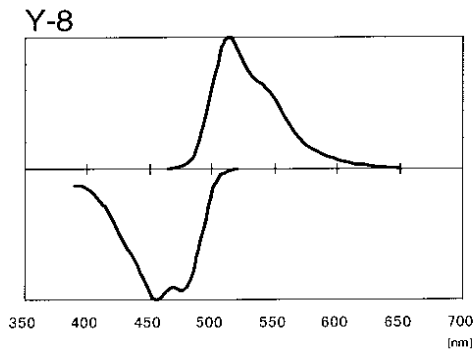
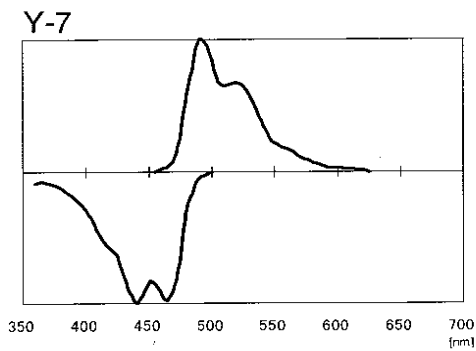


Exiting Wavelength: 430nm



Exiting Wavelength: 430nm

## Absorption and Emission Spectra of WLS<sub>7)</sub>

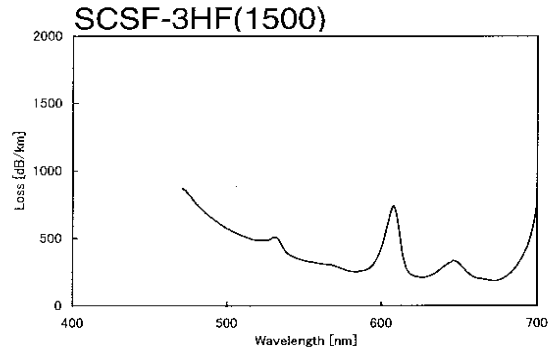
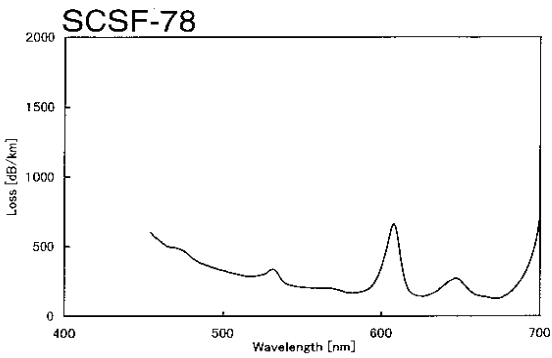
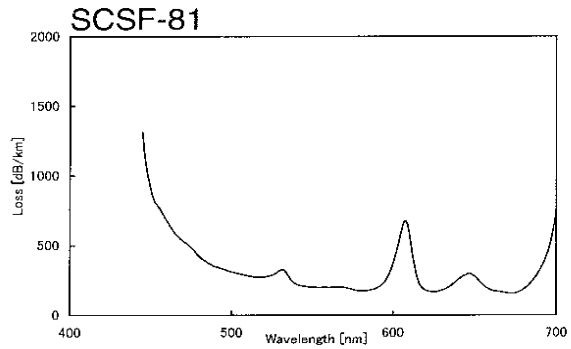
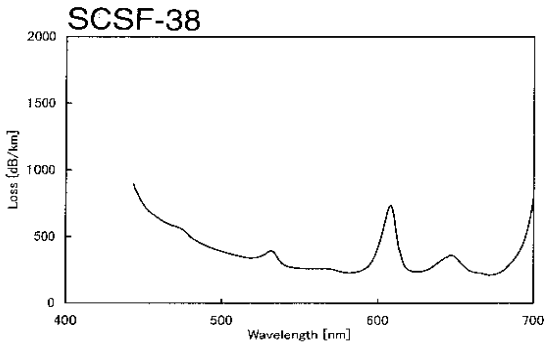


7) The spectra was measured by diluting dye with styrene monomer.

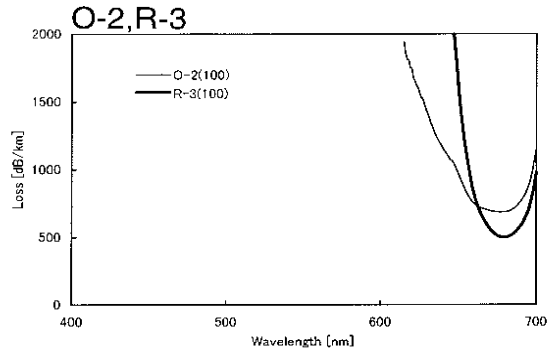
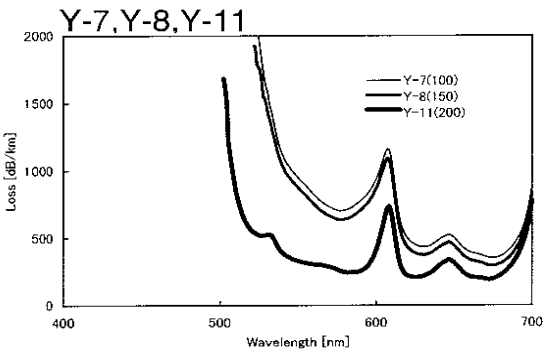


# Transmission Loss

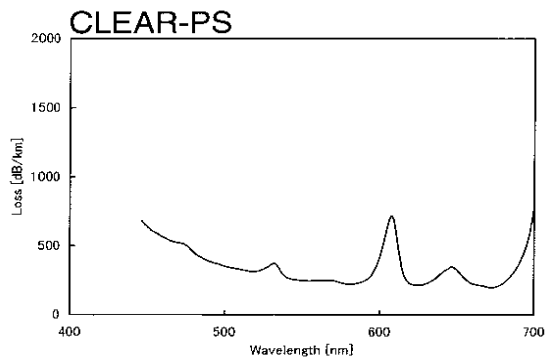
## Scintillating Fibers



## WLS Fibers



## Clear Fiber

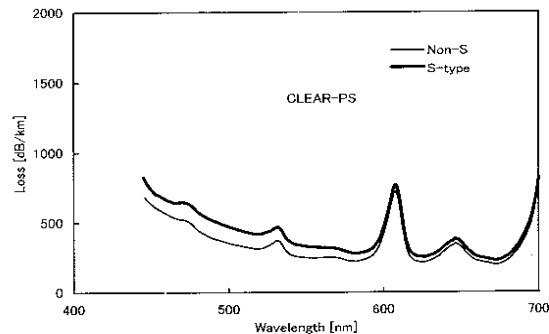
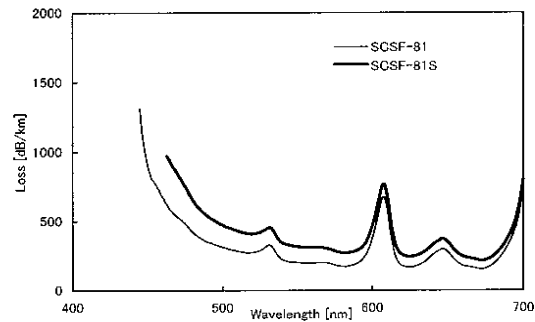
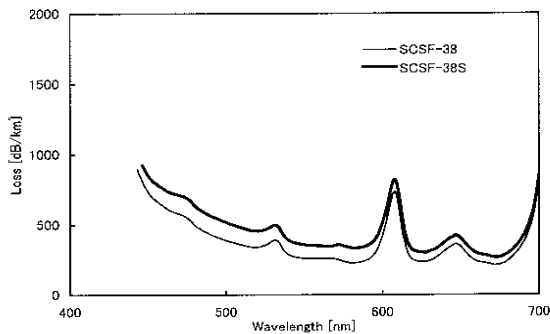


# Properties of S type Fibers

## Attenuation Length

	SCSF-38S	SCSF-81S	SCSF-78S	SCSF-3HF (1500)S	Clear-PSS
Atten. Length [m]	>2.8	>3.0	>3.5	>4.0	>8.0

## Transmission Loss



## How to Specify Fibers

- In order to specify fibers, the following points must be clarified.
  - Description
  - Cross-section (Round or Square)
  - Cladding (Single or Multi)
  - Non-S type or S type
  - Length and Dimension
  - Cane or Spool
  - Concentration of dye must be clarified in 3HF fiber and WLS fibers.

Examples of writing are as follows;

- SCSF-3HF(1500)M, 1.0D., 2000m on spools
  - Round fiber, Multi cladding, Non-S type, 1.0mm diameter, 2000m length.  
Fiber is put on spool, and the concentration of 3HF dye is 1500ppm.
- Y-11(200)S, 0.5D., 10000m on spools
  - Round fiber, Single cladding, S type, 0.5mm diameter, 10000m length,  
put on spools, the concentration of WLS dye is 200ppm.
- Clear-PSMS, 0.83SQ., 3m cane
  - Square fiber, Multi cladding, S type, 0.83mm square, 3m length cane.

# SCSN Plastic Scintillators

## Features of SCSN

### Polystyrene Base

Because of a special method of cross-linking the polystyrene, SCSN plastic scintillators have excellent mechanical properties. (See physical parameters mentioned below.) They are several times easier to form

than polyvinyltoluene-base scintillators.

### Large Size

SCSN plastic scintillators can be supplied in sizes up to 2400mm×1400mm.

## Formulations

Description	Light Output	Peak of Emission	Attenuation Length <sup>8)</sup>	Decay Time	Softening Point
SCSN-61	55% Anthracene	430nm	0.92m	2.5ns	95°C
SCSN-81	50% Anthracene	440nm	1.40m	2.5ns	95°C

8) Test samples' sizes are 1500mm×50mm×10mm.

Otherwise than descriptions mentioned above, various scintillators are available.

## Physical Parameters of SCSN and Other Bases of Scintillators

Test Subjects	Tensile Strength (kg/cm <sup>2</sup> )	Rockwell Hardness (M•Scale)	Izod Impact Energy (kg•cm/cm)	Deformation Temperature (°C)	Retention of the Bending Strength Against the Radiation(%)	Aging Effect
Test Method	ASTM D638	ASTM D785	ASTM D256	ASTM D648	ASTM D790	—
SCSN	660	81	2.2	95	96	○
Polystyrene	500	84	1.2	82	105	×
Polyvinyltoluene	260	89	1.9	73	89	×
PMMA +15% Naph	490	64	2.4	55	<5	—
PMMA	780	100	2.2	100	<5	○

The fourth item, the deformation temperature, was measured at a maximum stress of 264 psi.

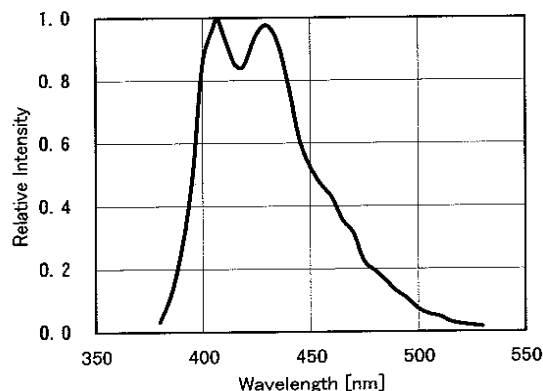
The fifth item, the retention of the bending strength, shows the change after an irradiation of  $5 \times 10^7$  rad of Co-60.

The last item, the aging effect refers to the changes appearing in a polished surface after a one week experience of the repetition of 8 hours at 70°C and 16 hours at room temperature, in a condition of 100% relative humidity.

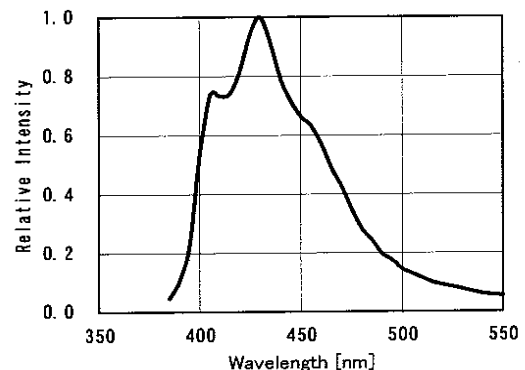
○ : no remarkable change. × : remarkable change.

## Emission Spectra

SCSN-61



SCSN-81



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